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INFORMATION ON OVER-THE-HORIZON RADAR
PART IV

(UNCLASSIFIED TITLE)

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CONTENTS

INTRODUCTION	1
AIRCRAFT RANGE CONSIDERATIONS	2
AIRCRAFT SPEED CONSIDERATIONS	4
COMMERCIAL TRAFFIC ANALYSIS	6
SUMMARY OF IDEAL IONOSPHERE MUTE SITE DETECTION POTENTIALITIES	8
IONOSPHERIC PROPAGATION CONSIDERATIONS	8
COMMUNICATIONS	12
COST OF THE MUTE SITE	12
ELECTRONIC COUNTERMEASURES	12
RECOMMENDATIONS	12

CONTENT

The use of a receive only site in conjunction with an active over-the-horizon radar to obtain additional coverage at low cost is considered. An FLR-9 receiving array or an FRD-10 receiving array in conjunction with an FPS-95 radar is discussed.

PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing.

AUTHORIZATION

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USE OF FLR-9 AND FRD-10 ANTENNAS IN CONJUNCTION WITH FPS-95 OVER-THE-HORIZON RADAR

INTRODUCTION

One of the tasks assigned in the DOD Memo Log No. 64-325 of 7 February 1964 is a study of the bistatic operation of an over-the-horizon radar for the detection of aircraft. Bistatic operation for this study is defined as operation with one active radar, transmitting and receiving on a single antenna, and one or more additional stations remotely located and equipped for receiving only, called mute sites. The active site will be the FPS-95 radar. The mute sites would use either an FLR-9 or an FRD-10 antenna system; all calculations are based on the FLR-9 characteristics. The gain versus frequency characteristics of the FLR-9 are shown in Fig. 1 and the vertical angle versus frequency characteristics in Fig. 2. These characteristics were obtained from the test report on the San Vito installation - Technical Document Report No. 200TRR-06A.

An active radar site at Diyarbakir, Turkey, was assumed and mute sites assumed to be at: Chick Sands, England (FLR-9 installed); Edzell, Scotland (FDR-10 installed); San Vito, Itlay (FLR-9 installed); Karamursel, Turkey (FLR-9 now being installed); and Rota, Spain. Also the Peshawar, Pakistan FLR-9 installation has been considered. Rota and Peshawar have been included as illustrative of siting considerations different from those of the existing or planned sites.

The task was pursued as a dual one, the two aims being: first, assuming an appropriate ionosphere to which characteristics could be reasonably assigned at the user's option, to determine whether and to what extent the addition of a mute site to a system can augment the detection capability of the system; and second, taking into account the normal range of variation of ionosphere characteristics, to determine whether and to what extent the ionosphere will provide a bistatic operation.

The location of any mute site recommended was required to be one of the locations listed above; the traffic to be observed was to be assigned equal preference, without regard to speed, location, or path, in all portions of the observed region.

In order to evaluate comparatively the various possible mute sites a study was undertaken of the scheduled civilian passenger flights within the Soviet Union. Schedules were taken from the Official Airline Guide, World Wide Edition, October, 1963. A "Schedule Day" was assembled, composed of all listed domestic flights. This list included several flights which are of less than daily frequency, (such as Monday-Wednesday-Friday Only), but excluded some deemed to be listing errors because of

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unreasonable speeds. Also omitted were the international flights, because of their weekly rather than daily base and because the low volume makes their contribution to the total count negligible. Each take-off and subsequent landing was counted as a flight even though either or both may have been intermediate stops on through flights. Each flight counted was counted singly, and no account was taken of the possibility of multiple sections. This Schedule Day is then a list of flights taking place within a normal 24 hour period which is an approximation only for any specific day or time of day.

Ground ranges from the aforementioned sites to the terminal cities of the scheduled flights were calculated, and assuming a great circle path and uniform forward speed flight distances and speeds were obtained. In some instances the speeds were compared with the cruising speeds of the aircraft scheduled and agreement was rather good, except for some of the very short flights in which a large portion of the time is probably consumed in take-off and landing pattern involvement. Observable speeds and ranges with respect to the various sites were calculated.

AIRCRAFT RANGE CONSIDERATIONS

From the data there were found to be 1328 flights during a schedule day, logging a total of 157,880 aircraft minutes. The average flight duration for all types of aircraft is just under 2 hours, and the mean airborne count for the day is 112. During peak traffic hours there may be as many as 221 aircraft in the air at one time. Figure 3 gives the Aircraft Count versus Time record of the schedule day. The cities of flight termination are 141 in number, of which 52 have fewer than 5 terminations per day, while only 42 have 20 or more take-offs or landings per day. Three cities, Moscow, Rostov, and Leningrad, together account for more than 17% of the flight terminations. For comparison, the New York Air Traffic Control Center of the Federal Aviation Agency has had more than 3000 flights reporting during a single 10 hour period.

Of the total traffic, flights comprising 126,970 aircraft minutes are in range of Diyarbakir during some portion of the flight, accounting for 80.4% of the total. The remaining 19.6% of the total cannot be recovered by a mute station regardless of placement because the target will not be illuminated by the active radar. Additional active radars would be necessary to observe this portion of the traffic. No extensive study has been made of the siting of such additional radars. Now, restricting our attention to those flights which are in range and potentially visible from Diyarbakir at some time during the flight, let us consider the range situation with the other possible sites.

The term "in range" has been limited with respect to an active site to mean that the target is between 500 and 2000 nautical miles distant from the site. Within these limits, for a target to be "in range" from a mute site it must be in a location which permits illumination from the active and the mute site at a common frequency. The mutual illumination ionospheric circumstances are discussed elsewhere in this report; for our purposes here range compatibility has been assumed in all instances in which the range to an illuminated target from the mute site is between 500 and 2000 nautical miles and in addition coincides with the range from the active site within plus or minus one 500 nautical mile range bin. In the following discussion of possible potential mute sites, the term "in range" with respect to the mute site refers to this degree of range compatibility.

Karamursel, Turkey, is on the western end of Turkey and a little more than 500 nautical miles from Diyarbakir. From here 96% of the aircraft minutes illuminated by Diyarbakir are in range during some portion of the flight. Regions of range-visibility can be seen in Fig. 4 which shows the 500 and 2000 nautical mile constant range contours from Diyarbakir and the 500, 1000, 1500 and 2000 mile contours from Karamursel. One circumstance which sets limits on the coverage to be achieved by any mute site is illustrated by the intersecting 10 degree sectors out of Diyarbakir and Karamursel in this figure. If the mute site observes a sector 10 degrees in width, it can only detect targets in the small area common to the two sectors, an area much smaller than that illuminated by a 10 degree beam from the active site, except where the two sites are almost in line from the target area. Unfortunately, the more nearly the two sites are in line the more nearly the performance of the system approaches that of the primary site alone.

Figure 4 puts the 2000 nautical mile range contour from Karamursel at Lake Balkhash. The excluded areas are east of the 2000 mile contour plus to the west all of Rumania and Bulgaria along with southwestern Russia. Solely from a range standpoint, Karamursel is a site which should be considered.

The next site to be considered is San Vito, Italy. From here 86% of the aircraft minutes illuminated by Diyarbakir are available. As Fig. 5 shows, from San Vito all of the Soviet Union is covered west of the Ural Mountains and the Ural Sea, but very little east of this line. However, the illuminated traffic is preponderantly west of this line.

The two sites in the United Kingdom, Edzell and Chick Sands, show about equal range capability, Chick Sands being about 1900 nautical miles and Edzell about 2000 nautical miles from Diyarbakir. Chick Sands was selected to show range contours in Fig. 6. Chick Sands will have in range 69% of the aircraft minutes illuminated by Diyarbakir, and Edzell 68%.

Removing the mute site further from the active site rapidly decreases the area of visibility, as can be seen from the fact that Rota, Spain, will have in range only 12.5% of the aircraft minutes illuminated by Diyarbakir, compared to 69% for Chick Sands and 96% for Karamursel. Therefore, Rota is not considered seriously as a possible mute site in conjunction with Diyarbakir. On range consideration only, the sites in the United Kingdom are of some value, but they are near the maximum tolerable separation from the active site chosen. Sites more than 2000 nautical miles from Diyarbakir should not be considered.

Peshawar, Pakistan, is a site approximately 1500 nautical miles to the east of Diyarbakir. The range contours from Peshawar are shown in Fig. 7. Peshawar will have in range 67% of the aircraft minutes illuminated by Diyarbakir and most of these will be traffic which is invisible to the other mute sites described. Therefore, Peshawar is worth further consideration as a mute site.

In summary, the findings of the range-only considerations are: (1) Mute sites more than 2000 nautical miles from the active station should not be considered; (2) Karamursel, San Vito, Chick Sands, Edzell and Peshawar (in the order listed) merit further consideration; and (3) Peshawar fills in areas not covered by the other mute stations mentioned.

AIRCRAFT SPEED CONSIDERATIONS.

Inasmuch as a mute station cannot increase a detection area beyond the region visible to the active station alone, any mute site contribution to detection capability of a system must come about by observing targets which have radial speeds too low to be seen from the primary site. To facilitate a discussion of this objective, let us define some terms needed to describe the speed observation capability of a mute site.

An aircraft is considered traveling in a path radial to a radar site if the aircraft path lies in the verticle plane containing the radar site, the point of reflection of the beam at the ionosphere, and the center of the earth. On the other hand, if the path intersects this plane, the course is non-radial and one speaks of an "azimuthal displacement" which is the angle through which the path would have to move to coincide with the reference plane. For single site operation the observed speed V_r of a target is the in-line-of-beam component of the target ground speed V_f. If the beam arrives at the target at a vertical angle α above the horizon, and the azimuthal displacement of the path from radial is β, the observed speed is

(1) $V_r = V_f \cos \alpha \cos \beta.$

For the FPS-95, the minimum detectable V_r is 75 to 100 knots for reasons of clutter elimination, and (from the above expression and excepting the special case where $\alpha = \beta = 0$) V_f must be greater than V_r. For a target of a given speed at a given position with respect to the radar system a "visible sector width" is defined, which is the azimuthal angle through which the target path may rotate about that point without its V_r becoming less than 100 knots. For the single station case this sector, composed of two elements, is centered one about a radial-approach path, the other about a radial-recede path. For bistatic operation the width and center of this visible sector depend on the angular separation (about the azimuthal axis) of the two sites, as viewed from the target. This is called the "site separation" and denoted by d in the following description and figures. The degradation in speed $\frac{V_r}{V_f}$ suffered by a target is called its effective aspect factor.

From equation (1) above, the effective aspect factor equals cos α cos β in the single site case. Figure 8, a plot of Vertical Angle of Arrival versus Width of Visible Sector, shows the range of variation which can realistically be ascribed to α for certain aircraft speeds of interest. For convenient reference, ground ranges reached via a rather normal F layer (height 220 km) are shown opposite the vertical angles which would apply. Since the beam is restricted to fairly small vertical angles which will be approximately equal for the two sites one neglects cos α in the following treatment of the bistatic situation. Figure 9a shows the geometry of the single site case, in which all angles shown are azimuth angles. In this figure, $V_r = V_f \cos(a-b)$, for a target on the path shown and detected by S_1.

Figure 9b shows the addition of mute site S_2. In this situation, the detection by S_1 remains unchanged and the speed observed by S_2 is

$$(2) \quad V_r = \frac{V_f}{2} \left[\cos(a-b) + \cos(a-b-d)\right].$$

Figure 10 is a plot of the effective aspect factor for observations at S_2 and for values of d at 20 degree intervals using this equation. It is apparent that (1) the line of maximum response is not radial to either site, but is the bisector of d, and the line of minimum response is perpendicular to the line of maximum response, and (2) the maximum response decreases, or the minimum detectable forward velocity as shown along the right hand edge of the plot increases, as d increases. Here the d = 0 curve is equivalent to single station or in-line operation, and the d = 180 curve applies for targets directly between the two sites.

The above has some rather adverse implications insofar as mute site versatility is concerned. For it can be seen, and Fig. 11 illustrates by example, that a constant - d path is an unlikely one for an aircraft to follow; hence for any target an ever-changing reference line of maximum response is experienced, with consequent data analysis complication. For instance, a constant speed track would be a freak. Figure 11 is a plot of values of d versus distance from the line between the two sites measured at right angles and from the midpoint of the line for various site-to-site ground distances as noted. The significance of the line of measurement, the line which is the perpendicular bisector of the line between the sites, is that all points on this line are at equal range from the two sites and this is therefore prime coverage region. In addition the point thus located and the two sites all lie on and define a circle of constant d. It can be seen from these curves that d may change appreciably during the course of a long flight. Moreover, there are only limited regions in which the mute site can be effective for a chosen aircraft speed. The task does become less formidable when one thinks of high speed aircraft, but it is here thatthe primary station performs best and there is correspondingly the least need for data fill-in. The data interpretation difficulties, however, persist at all speeds. Increased width of visible sector is obtained only by trading in low speed cut-off.

COMMERCIAL TRAFFIC ANALYSIS

Now referring again to the traffic to be expected in the region, the schedule day is composed of several aircraft types of different speeds, as follows:

12% of aircraft minutes are of Antonov 2 (AN) having a cruising speed of 97 knots,

8% Lissunov-2 (LI), Russian version of DC-3, having a cruising speed of 130 knots,

38% Ilyushin IL-14 (Y4), cruising speed 195 knots,

22% Ilyushin 16-18 (Y8), cruising speed 350 knots, and 20% jets, speeds not specified.

Because of the 100 knot lower limit one cannot see the first 12% of this traffic. Of the next 8%, traveling at 130 knots, one cannot obtain all-azimuth coverage with less than three stations, as can be seen from Fig. 8. This plot shows the width of one element of the visible sector as seen by an active site for various aircraft speeds and vertical angles of arrival. Here it can be seen that the best coverage, single station, of a 130-knot aircraft is a visible sector width less than 90 degrees. The maximum coverage contribution of a mute site for this aircraft, occurring in regions where the site separation is about 60 degrees, is an increase in the visible sector width (one elemtnt) from about 80 degrees to 97 degrees. Where the site separation is greater than about 80 degrees, the aircraft will be invisible at the mute site. Figure 11 shows that along the equidistant line, the region in which the target is invisible extends out 600 miles from the line between two sites spaced 1000 nautical miles apart. The region of greatest mute site contribution, at about 60 degree site separation, occurs about 900 nautical miles out along this line, beyond which distance the visible sector narrows progressively, approaching the single site coverage for very great distances. This plot illustrates some of the reasons why it is inadvisable to separate the sites by distances much greater than 1000 nautical miles, particularly for that 58% of the traffic which is below 200 knots.

A snapshot of airborne traffic was taken at 1305 hours on the schedule day, and hypothetical observations at Diyarbakir and Karamursel were tallied, Karamursel being chosen for its nearness to Diyarbakir and its relatively favorable range-compatibility score as described above. This tally includes those aircraft either taking off or landing at 1305 and disagrees thereby with the airborne count of Fig. 3. The tallied results for Diyarbakir, S_1 and Fig. 12, and Karamursel, S_2 and Fig. 13, are as follows:

S_1 Observations

There are 224 aircraft in the air at 1305, and of these

- 59 are not illuminated by S_1,
  - 56 because of range
  - 3 because of azimuth.
- 165 are illuminated by S_1, of which
  - 87 are visible to S_1 and
  - 78 are invisible to S_1 because of low radial speeds.
    - 16 of these have ground speeds less than 100 knots.
    - 62 have radial speeds less than 100 knots:
      - 46 have ground speeds less than 200 knots,
      - 11 have ground speeds of 350 knots, and
      - 5 are jet aircraft.

S_2 Observations

Of 165 aircraft illuminated by S_1,

- 75 are visible to S_2, of which
  - 11 are not visible to S_1 because of low radial speeds
    - 7 of these have ground speeds less than 200 knots,
    - 4 have ground speeds of 350 knots.
- 90 are not visible to S_2,
  - 16 have ground speeds less than 100 knots,
  - 17 are out of range (compatibility), and
  - 57 have observed speeds less than 100 knots.

Thus Diyarbakir alone is capable of seeing 87 aircraft out of 224, and Karamursel as a mute site increases system capability to 98 detections. It should perhaps be emphasized here that while under optimum conditions one can make 11 additional detections in this particular instance, their invisibility to the active site makes them extremely difficult to locate or identify as to range, speed, or path, since detections of both range and speed are composites of outgoing and incoming rays. This remark implies a real dependence on the active site observations and on cross matching with them for accurate mute site target interpretation. If one foregoes target interpretation and settles for a population count without benefit of elimination of duplicated detections, then the value of the operation is reduced practically to a normal-abnormal determination which could only be of possible limited use in terms of a particular mission.

SUMMARY OF IDEAL IONOSPHERE MUTE SITE DETECTION POTENTIALITIES

It appears that any benefits to be derived from bistatic operation can only be over limited ground regions for particular aircraft speeds and paths and at a considerable expense for data processing requirements.

Any mute sites selected should not be much farther from the active site than 1000 nautical miles, eliminating all but two from the list of possible sites. The selection should preferably be on a mission basis rather than for general purpose regional coverage.

The differences between the two remaining sites, Karamursel and San Vito, are in the trade off area of range versus speed versus visible sector width and are relatively minor. For general purpose coverage, no appreciable sacrifice would accompany a selection made for non-geometric reasons.

The 10% detection increase indicated in the sample included herein is felt to be an optimistic figure and one which cannot be realized at will.

IONOSPHERIC PROPAGATION CONSIDERATIONS

Using the ionosphere to obtain over the horizon coverage is not as simple as setting up on a frequency and operating. One must change frequency according to the time of day, time of year, sunspot cycle, distance to be covered and the direction of propagation. Therefore an investigation of the ionosphere propagation for the active site and the possible mute sites was undertaken.

The National Bureau of Standards Central Radio Propagation Laboratory (CRPL) issues monthly predictions of ionospheric conditions appropriate for computer analysis, and they have also compiled past records and have issued data for six months of 1954, a year of low sunspot activity, and for 1958, a year of high sunspot activity. July of 1954 and June of 1958 have been chosen for the two activity levels in this study.

With the CRPL supplied data one can calculate the critical frequency of the F_2 layer for vertical incidence rays and the maximum usable frequency (MUF) for a 3000 kilometer path for any latitude, longitude, and time of day. From there the MUF for any path distance within one ionospheric hop can be calculated.

To attempt to determine the feasibility of bistatic operation, it was decided to select regions in which one would hope to be able to detect targets and to determine the MUF for a path to that region from each site in turn. Locations were chosen along a constant bearing line of 346 degrees true out of Diyarbakir at ranges of 500, 700, 1500, and 1900 nautical miles. The MUF was calculated for an active radar at Diyarbakir and passive radars at Karamursel, Turkey, San Vito, Italy, and a point in Scotland. The MUF's were then compared.

Transmission losses in the lower ionosphere were also calculated for the described paths using the approximate equation

$$(3) \quad \text{Losses} \approx \frac{615.5 \sec \phi_E \, (1 + 0.0037S)(\cos 0.881X)^{1.3}}{(f + f_h)^{1.98}}$$

where X is the zenith angle of the sun, ϕ_E is the angle between the ray and the vertical, S is the sunspot number, f is the frequency of transmission, and f_h is the value of the earth magnetic field expressed as the gyro frequency. Combining these losses with the characteristics of the FPS-95 and with the spreading losses, the familiar range^4 factor of the standard radar equation enables one to calculate the relative power received at the FPS-95.

From CRPL data we also calculated the noise power which we may expect to receive, and obtained a figure for signal-to-noise ratio at the radar. This affords a basis for judgement of degradation in radar performance with change of operating frequency, in this case always toward a lower frequency than the MUF.

Table 1 shows the MUF's for the four sites, where 1 denotes Diyarbakir, 2 Karamursel, 3 San Vito, and 4 the United Kingdom, for the target locations as described above. If one examines this table it is seen that the MUF's for the mute sites are higher than those for the active site at the 500 and 700 nautical mile range points. At 1500 and 1900 nautical miles range the reverse is true. This points up a basic problem in this mode of operation. The MUF from the target to a mute site varies as the target moves out in range and on a given azimuth from the active site, because the target is continually getting either closer to or farther away from the mute site than the active site. As pointed out earlier, for a single active site and a single mute site there is a great circle on which the target is everywhere equidistant

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TABLE 1 - MUF FOR STATIONS 1 THROUGH 4 FOR DESCRIBED PATHS,

JULY 1954 AND JUNE 1958

	Target Range From Station 1	July 1954 Station 1	July 1954 Station 2	July 1954 Station 3	July 1954 Station 4	June 1958 Station 1	June 1958 Station 2	June 1958 Station 3	June 1958 Station 4
0000 Hours	500	7.4	9.03	12.79	15.11	12.98	16.35	22.32	24.28
	700	9.0	9.84	12.35	14.11	16.12	17.50	21.10	22.29
	1500	15.08	14.05	12.88	10.89	20.09	18.71	16.77	13.68
	1900	16.32	15.64	13.91	10.45	20.80	19.85	17.41	12.91
0400 Hours	500	6.33	8.09	11.47	13.95	11.30	14.34	20.04	23.29
	700	7.91	8.76	11.12	13.17	14.07	15.46	19.26	21.69
	1500	13.62	12.80	12.03	10.47	19.28	18.23	16.84	13.94
	1900	15.20	14.57	13.21	10.12	20.52	19.85	17.76	10.13
0800 Hours	500	7.64	9.89	14.30	16.63	10.64	14.06	20.95	25.52
	700	9.77	10.84	13.77	15.37	13.70	15.54	20.43	23.72
	1500	16.40	15.41	14.02	11.23	20.43	19.42	18.02	14.42
	1900	17.49	16.93	14.89	10.51	22.19	21.39	18.89	13.25
1200 Hours	500	5.62	6.96	9.77	11.50	9.87	12.84	18.72	23.05
	700	7.16	7.64	9.44	10.72	12.48	14.06	18.29	21.60
	1500	12.10	10.92	9.77	8.32	18.05	17.05	15.91	13.00
	1900	13.01	12.09	10.55	8.11	19.81	18.89	16.73	11.87
1600 Hours	500	4.46	5.49	7.74	9.79	9.08	11.55	16.44	20.26
	700	5.67	6.05	7.59	9.36	11.38	12.57	16.01	19.21
	1500	10.02	9.11	8.51	7.98	16.60	15.69	14.90	13.09
	1900	11.27	10.55	9.63	8.06	18.56	17.86	16.21	12.42
2000 Hours	500	7.09	8.92	12.40	13.69	12.17	15.34	21.04	22.93
	700	8.91	9.66	11.79	12.65	15.11	16.44	19.90	21.15
	1500	13.85	12.89	11.57	9.71	19.07	17.93	16.24	13.45
	1900	14.50	13.94	12.34	9.47	19.80	19.13	16.99	12.74

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from the two sites. For more than one mute site no single circle exists fulfilling this condition for all sites. Since the MUF varies with the path distance there is no match that will be equally good for the mute and active sites at all azimuths from the active site. Then the operator of the active site bears an enormous burden in the selection of an operating frequency to give all sites coverage, and in order to do this he has to sacrifice performance of the active radar. The problem is not a simple one and it would require extensive pre-calculated tabulations or a computer to solve for a frequency using vertical ionograms and slant range soundings made from the active radar.

A further complication at the mute site, mentioned briefly in connection with Fig. 4, is the wide coverage necessary at a mute site just to observe all ranges of a 10 degree illuminated sector out of Diyarbakir. A tabulation of bearing changes going from the near edge to the far edge of the sector at 346 degrees true out of Diyarbakir for each of the mute sites is Table 2. Karamursel shows approximately 61 degrees bearing change, San Vito shows a 63 degree change, and the United Kingdom sites show a 62 degree bearing change. This means that for this particular region a mute site must be capable of instrumenting at least 60 degrees of change in antenna pointing angles. For all operating conditions this capability at a mute site requires approximately 20 data processing channels operating concurrently.

Now let us consider the vertical antenna pattern of the FLR-9 in the light of needs from the various sites. Assuming reasonable ionosphere heights we find that for ranges of 1400 to 2000 nautical miles the angle of arrival of the beam is in the order of 2 degrees. It can be seen from Fig. 2 that at no frequency can one achieve such a low elevation. In Band C the lowest beam center has a vertical angle of about 12 degrees; in Band B the lowest beam center is at 24 degrees. This means that one hop coverage using this antenna is restricted to close-in ranges.

TABLE 2 - BEARINGS FROM STATIONS 2 THROUGH 4 FOR CONSTANT BEARING POINTS FROM STATION 1

Target Range From Station 1	Station 1	Station 2	Station 3	Station 4
500	346°	49°	72°	89°
700	346°	34°	62°	83°
1500	346°	3°	22°	49°
1900	346°	348°	9°	27°

COMMUNICATIONS

There must be some communications between active and mute sites. The amount necessary is dependent on the mode of operation of the active site. If random frequency selection is being employed a new frequency will be selected every three seconds, each change requiring a message. A new azimuth may be chosen, say every three minutes and either a new azimuth angle message or the program must be transmitted. These will require one channel capable of about 10 words a second.

In the traffic count operation, if the mute site is to fill in flights invisible to the active radar there must be some common point to which all data from all sites are transmitted and at which these data are compared for elimination of duplications. This requires a channel of 5 KC bandwidth from each site to the collection center and a computer at the collection center to perform the combined traffic count as seen by all sites.

COST OF THE MUTE SITE

The mute site has to have a data processor with a large capacity as well as a number of receivers, one for each active beam. The cost of this equipment is estimated to be a minimum of three million dollars. This is for the equipment only and does not include the cost of a room about 40 X 60 feet to house this equipment. In addition a computer or additional computer capacity at an estimated cost of $250,000 will be required at the active site to guide the operator in frequency selection.

For maximum effectiveness, an antenna system comparable to the antenna system of the FPS-95 should be installed at any mute site. This will raise the cost of a mute site to over ten million dollars.

ELECTRONIC COUNTERMEASURES

The mute site has an advantage in an ECM environment if it is assumed that the enemy will use directional antennas to enhance his jamming capability against the active site. This is particularly true if one can place the mute site far enough from the active site to put it outside the main beam of the jammer. No detailed study has been made of this situation, but it will be given further consideration.

RECOMMENDATIONS

In accordance with this study it is recommended that the FLR-9 and FRD-10 sites be not equipped to operate as bistatic sites in conjunction with the FPS-95.

1. The best site will, under ideal conditions, detect only an additional 10% of the scheduled civilian passenger traffic over Soviet Russia.

2. The requirement of a path from the active site to the target to the mute site necessitates lowering the operating frequency below the active site MUF, with consequently degraded performance of the active site.

3. The antenna deficiencies of FLR-9 and FRD-10 at the low angles required indicate that the amount of usable information received will be very low. The FLR-9 and FLR-10 antenna systems would require a very extensive ground screen to lower their beam angles.

4. The necessity for instrumenting at least 60 degrees of beam coverage at the mute sites significantly increases the complexity and cost of the data processing equipment at the mute sites.

5. The requirement for a computer to be used at the active site for frequency selection raises the cost of the active site.

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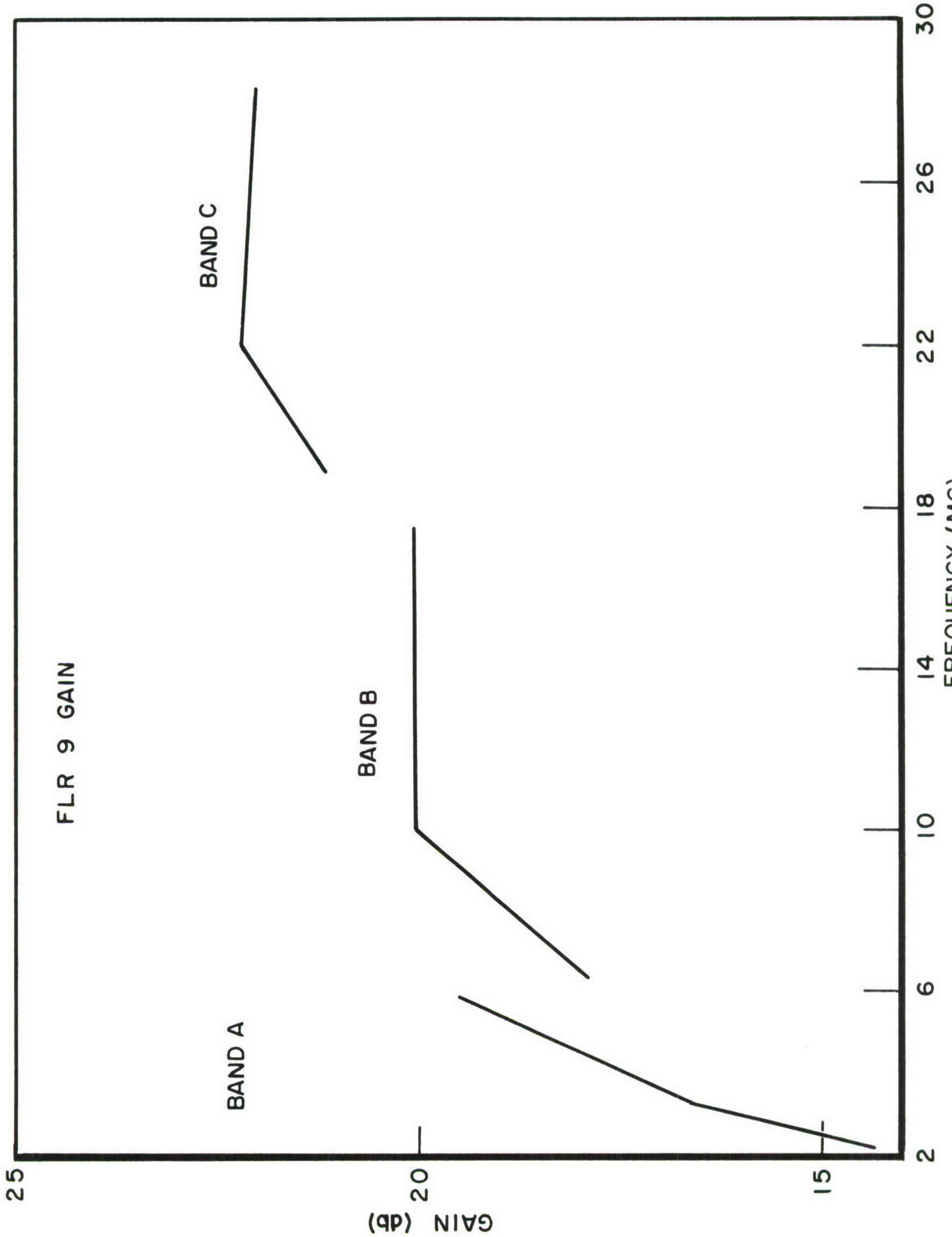


Figure 1

[redacted]

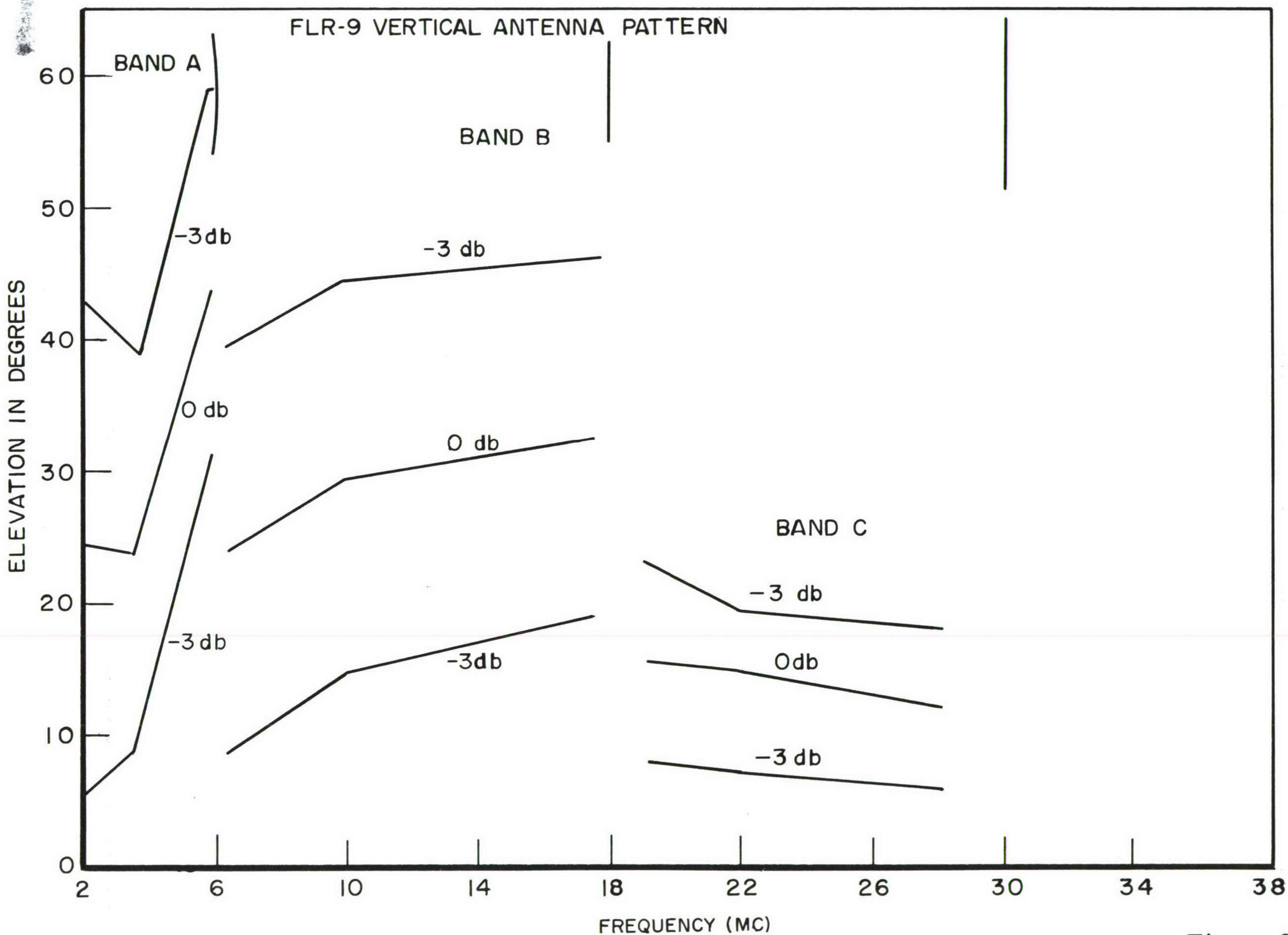

FLR-9 VERTICAL ANTENNA PATTERN
BAND A
BAND B
BAND C
-3db
O db
-3 db
-3 db
O db
-3db
-3 db
Odb
-3 db
ELEVATION IN DEGREES
0
10
20
30
40
50
60
2
6
10
14
18
22
26
30
34
38
FREQUENCY (MC)

Figure 2

[redacted]

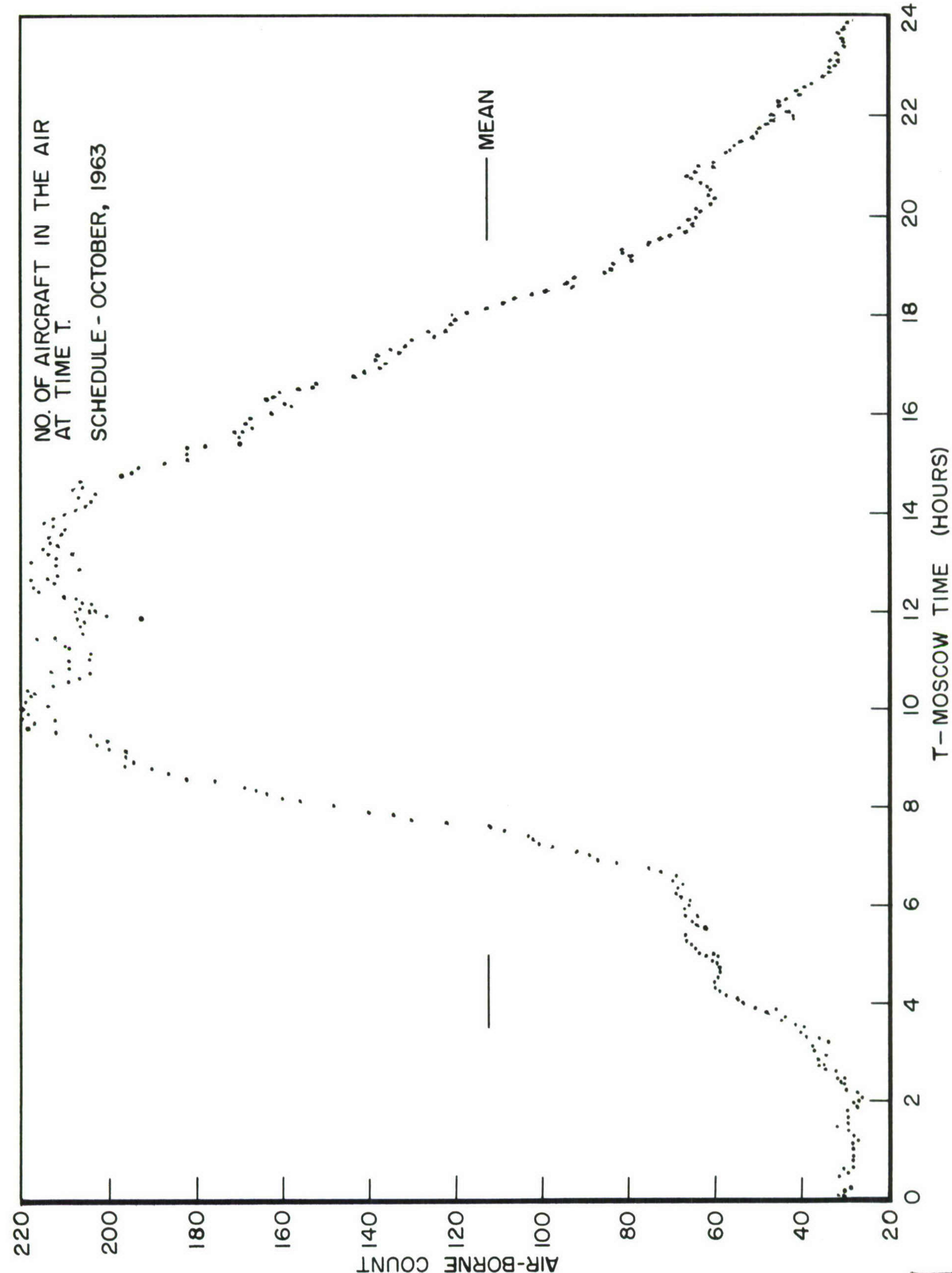


Figure 3

[redacted]

[redacted]

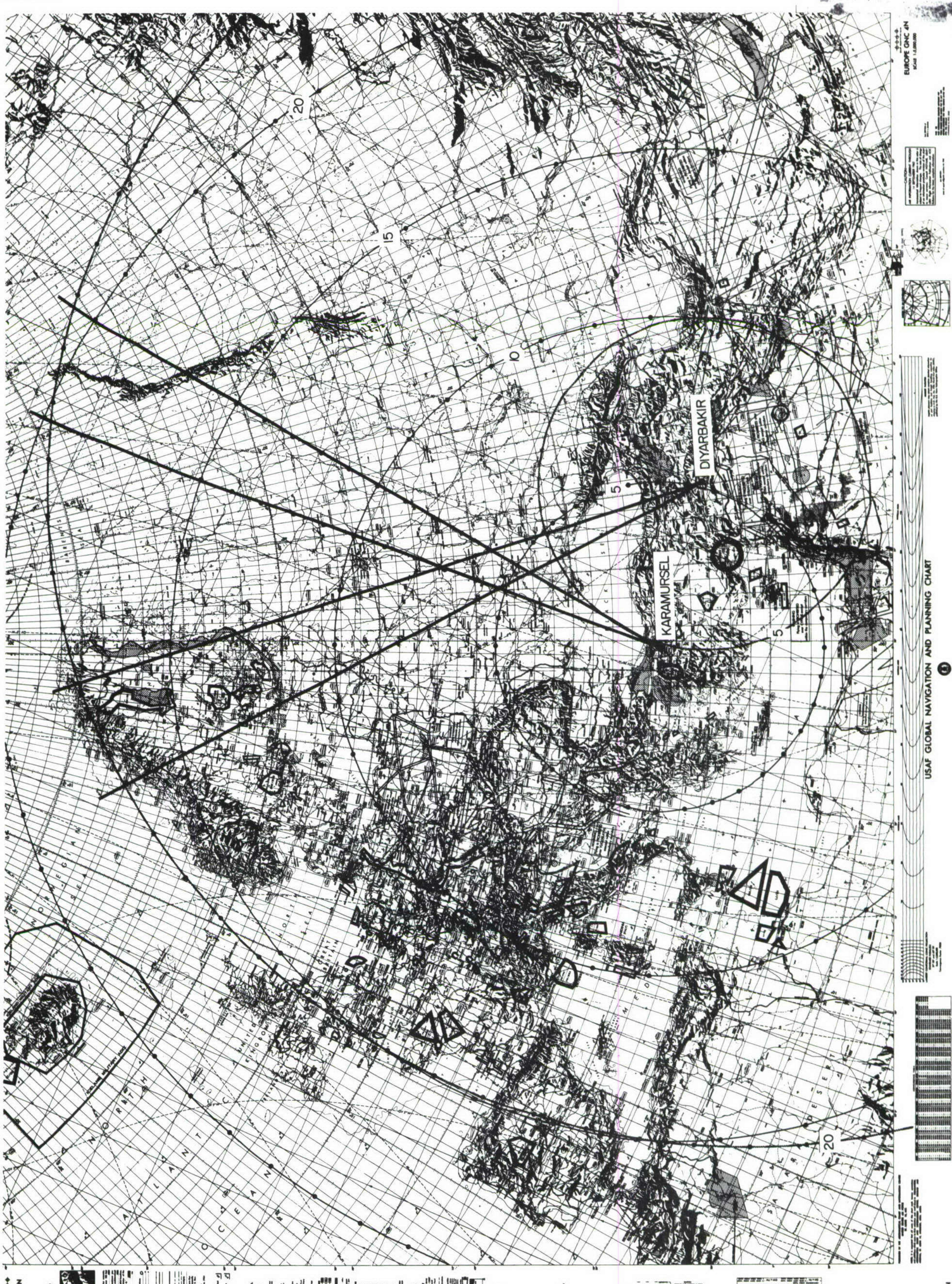
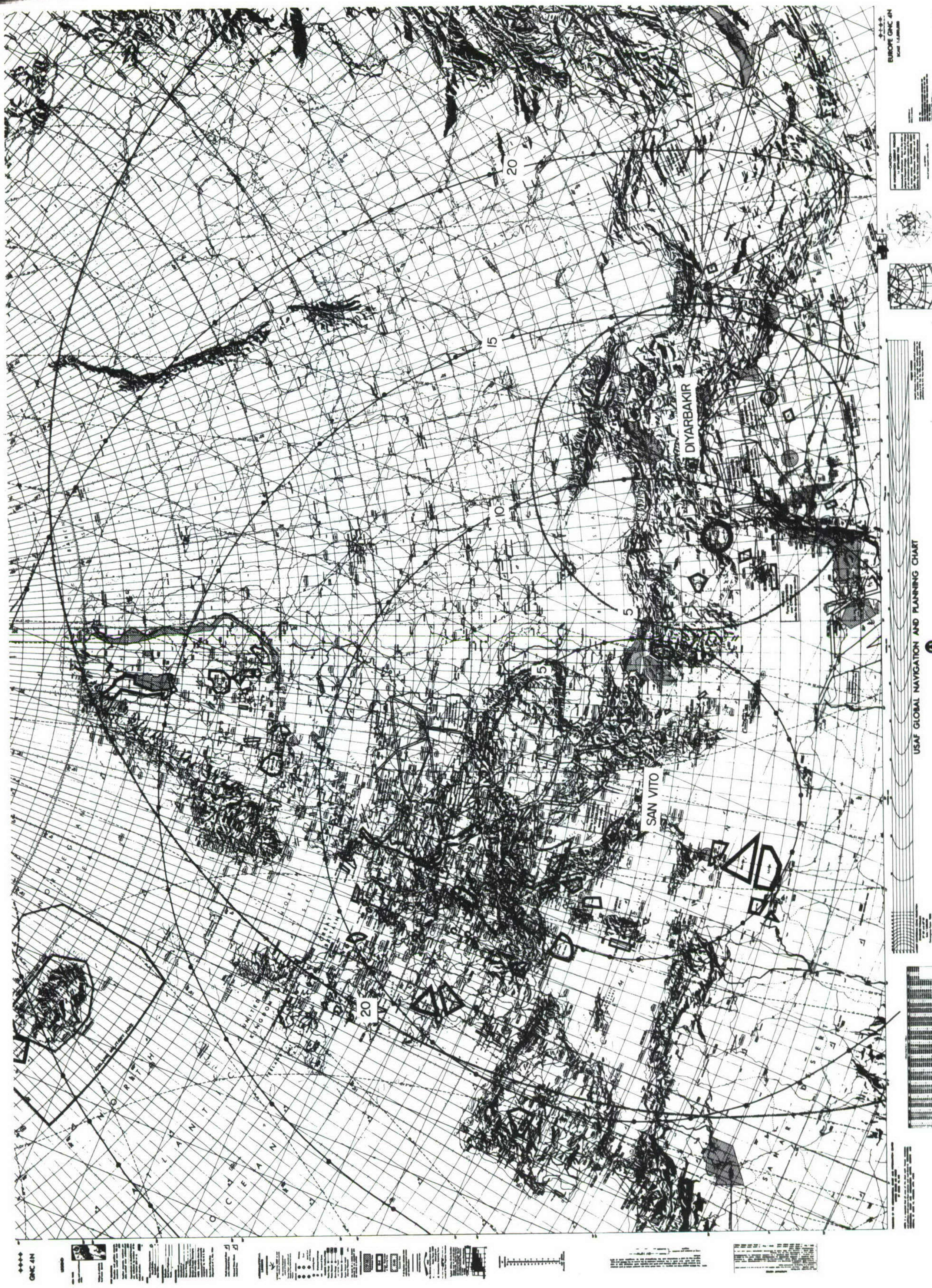


Figure 4

[redacted]



DIYARBAKIR
SAN VITO
USAF GLOBAL NAVIGATION AND PLANNING CHART
EUROPE GNC 4N
GNC 4N

Figure 5

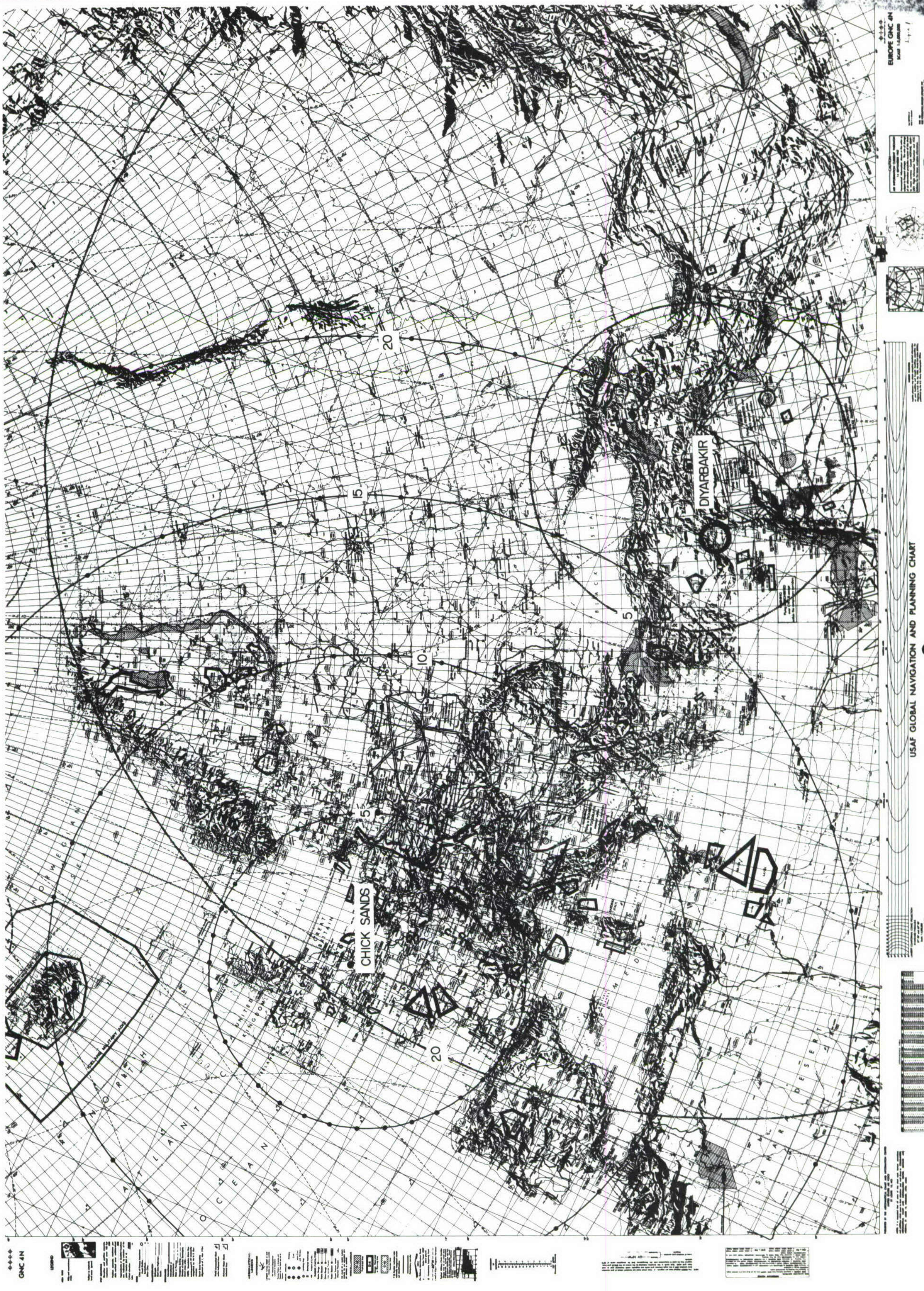

DIYARBAKIR
CHICK SANDS
USAF GLOBAL NAVIGATION AND PLANNING CHART
EUROPE GNC 4N
GNC 4N

Figure 6

[redacted]

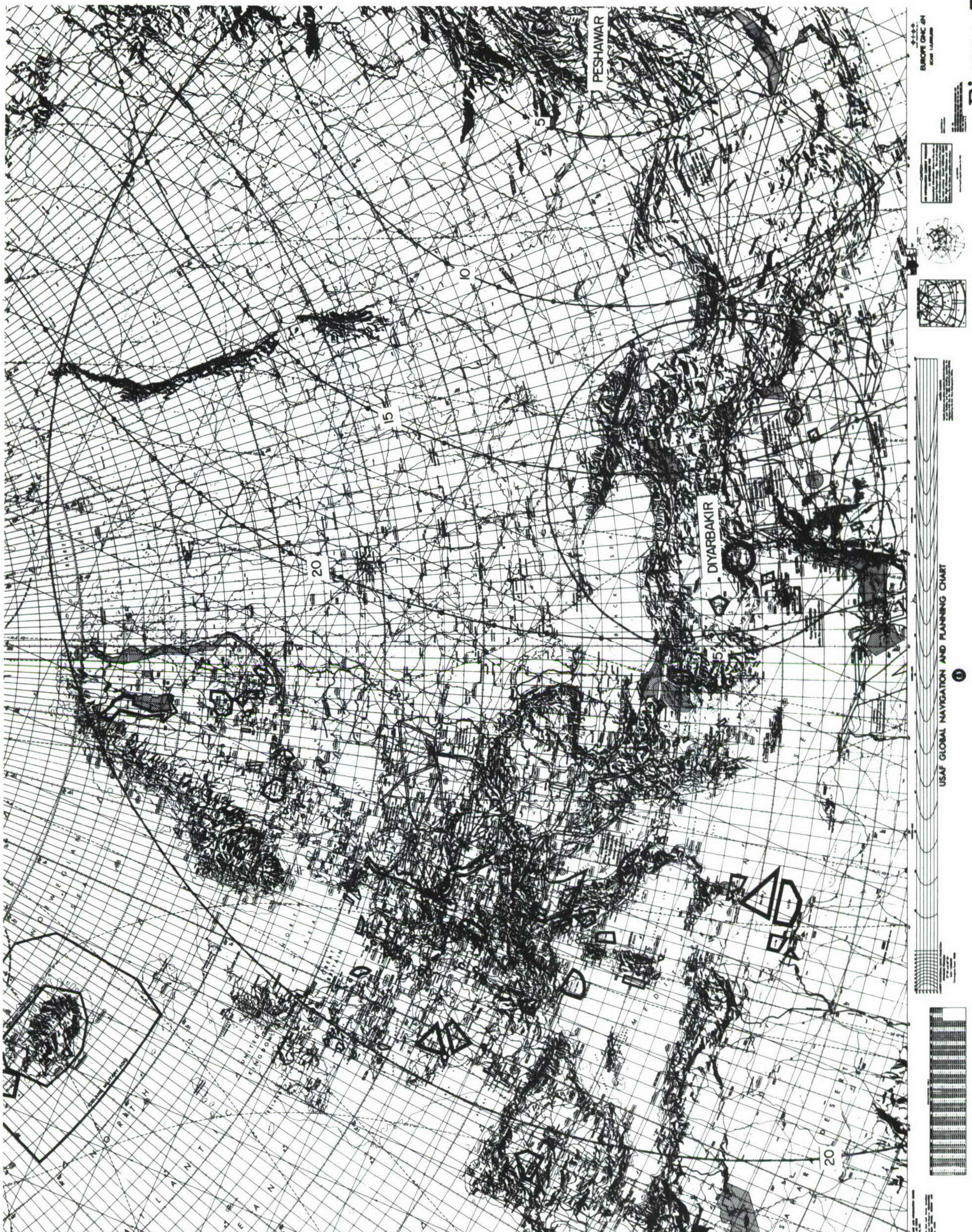


Figure 7

[redacted]

SECRET

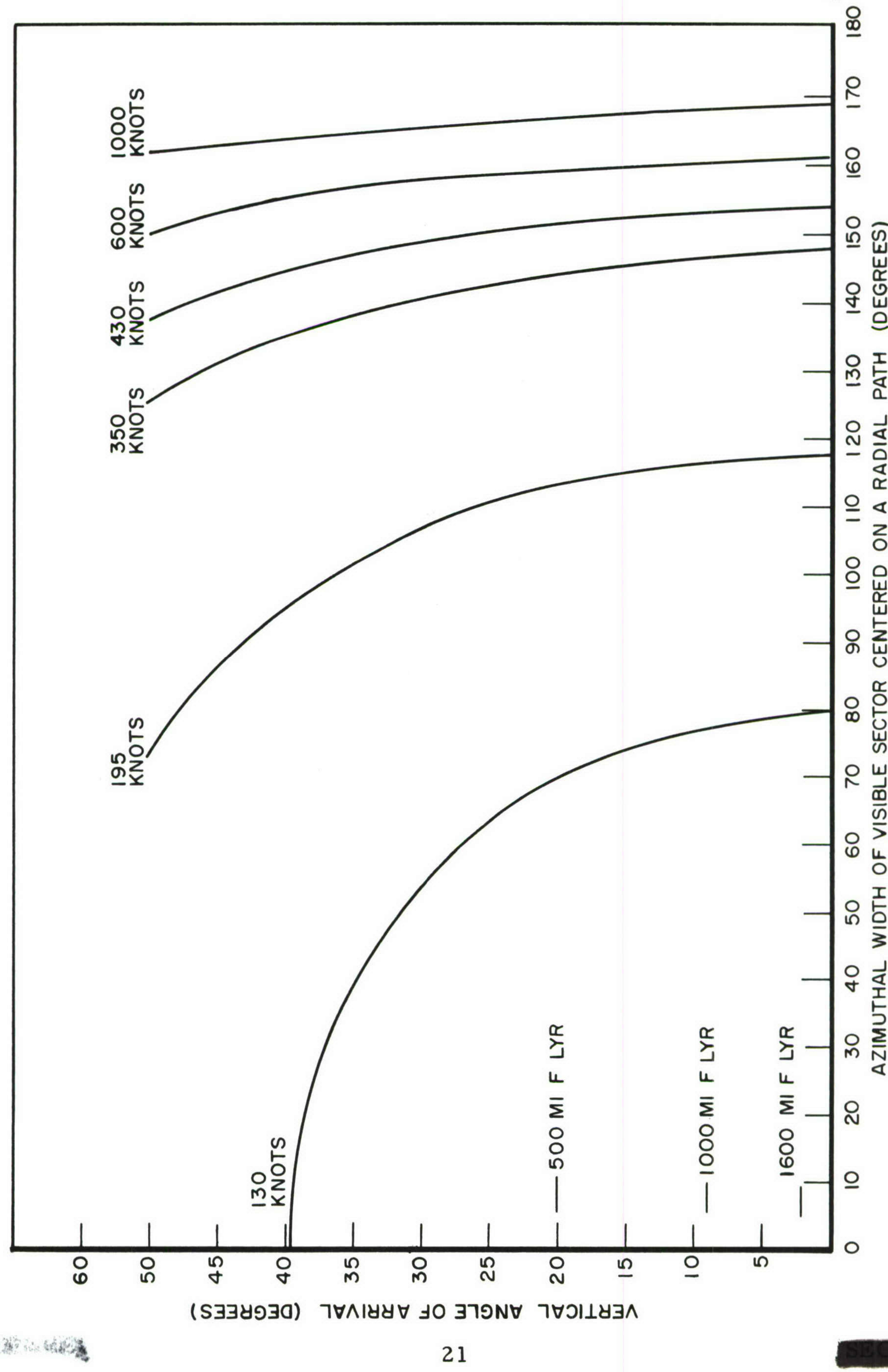


Figure 8

SECRET

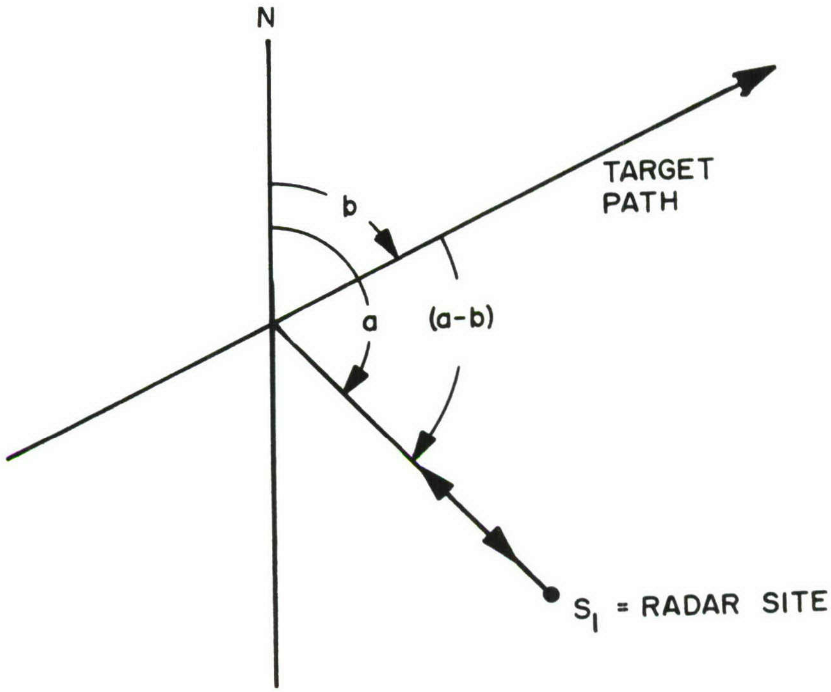


Figure 9a

[redacted]

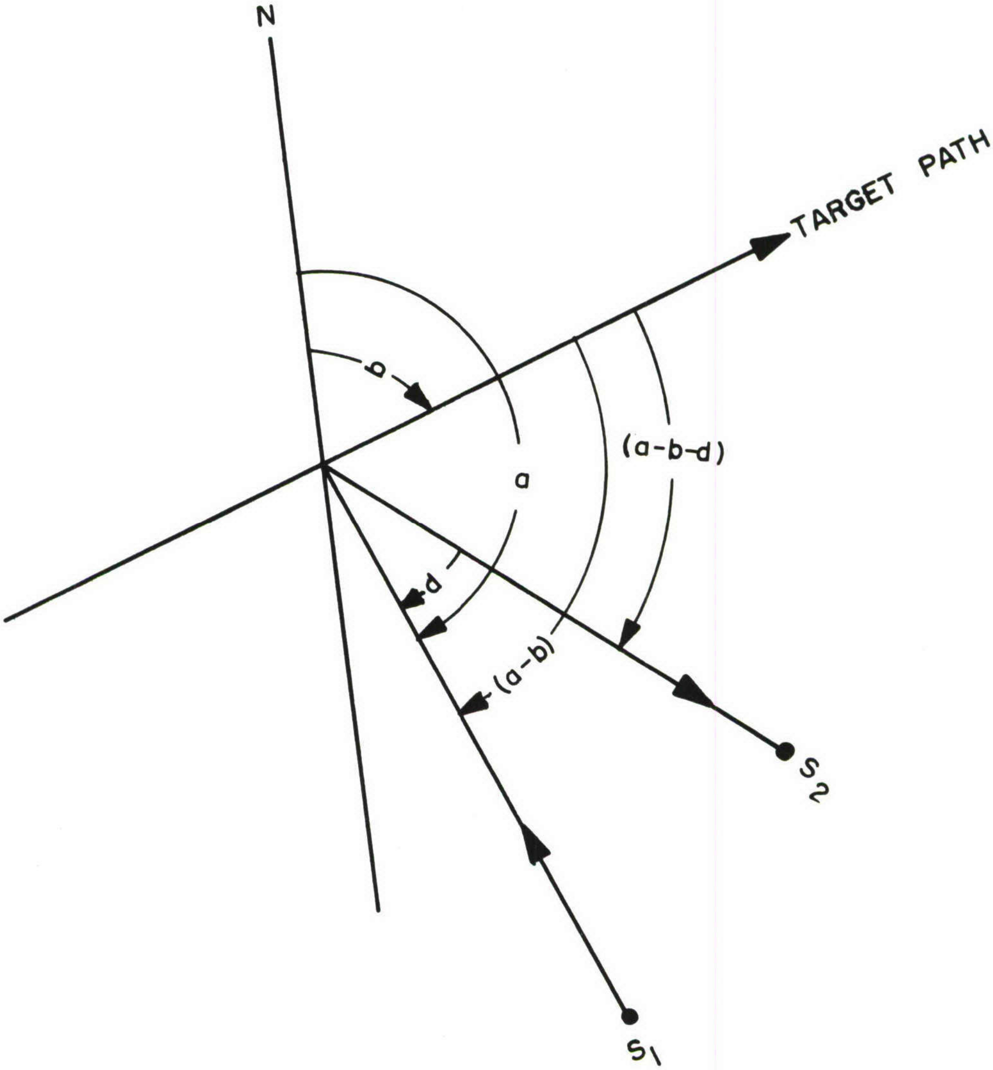
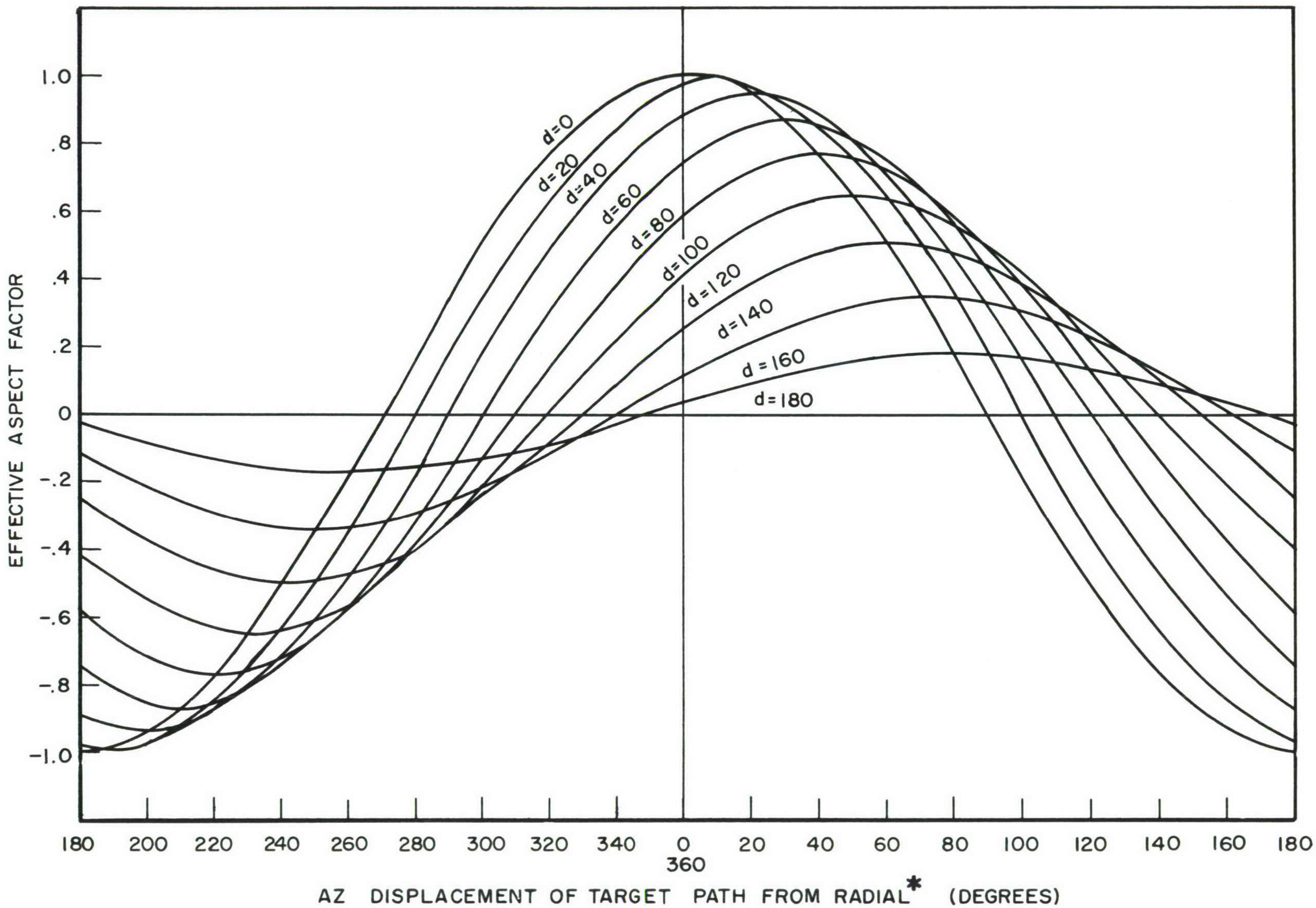


Figure 9b

[redacted]

[redacted]



* REF. "ACTIVE" LOC.

Figure 10

[redacted]

[redacted]

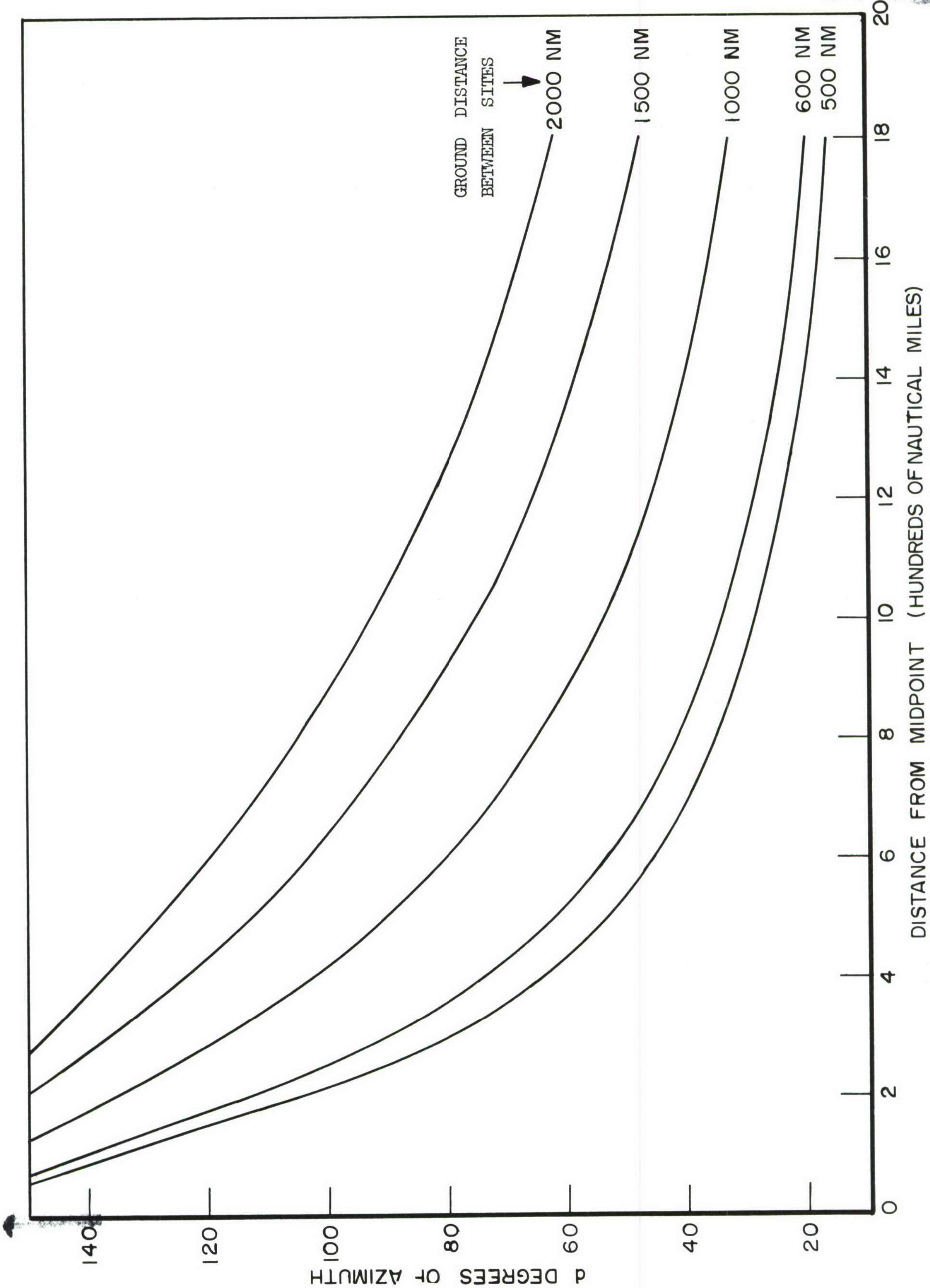


Figure 11

[redacted]

[redacted]

	290°-300°	300°-310°	310°-320°	320°-330°	330°-340°	340°-350°	350°-0°	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°	60°-70°
Range <u>1500-2000 Miles</u>														
Approach														
300+											3			
200-300									1					
100-200							1							1
Recede														
300+														
200-300											2			
100-200						1		1	2		1	1		1
Total						1	1	1	3		6	1		2
Range <u>1000-1500 Miles</u>														
Approach														
300+							1							
200-300					1	1	2			1				1
100-200							2	1	1	1		2		
Recede														
300+														
200-300						1				2		1		
100-200					1	1		1		3		1	1	1
Total					2	3	5	2	1	7		4	1	2
Range <u>500-1000 Miles</u>														
Approach														
300+					1									
200-300					1	3	3				1			1
100-200				2	4	1	4	1	2		1			
Recede														
300+							1			1				
200-300					1	1	1			1				1
100-200				1	2	1	2	1	3	1				2
Total				3	9	6	11	2	5	3	2			4
TOTAL				3	11	10	17	5	9	10	8	5	1	8

Fig. 12 - Wall Display S_1 - 1305 Hours - Schedule Day

[redacted]

[redacted]

	290°-300°	300°-310°	310°-320°	320°-330°	330°-340°	340°-350°	350°-0°	0°-10°	10°-20°	20°-30°	30°-40°	40°-50°	50°-60°	60°-70°	70°-70°+
Range 1500-2000 Miles															
Approach															
300+										1					
200-300															1
100-200												1	1		
Recede															
300+															
200-300											3	1	1		1
100-200									3			1		1	
Total									3	1	3	3	2	1	2
Range 1000-1500 Miles															
Approach															
300+											1				
200-300							1		1	1	1				1
100-200								3		3	1	1	1		
Recede															
300+															
200-300										1			1		1
100-200							1	1			4	1	1		1
Total							2	4	1	5	7	2	3		3
Range 500-1000 Miles															
Approach															
300+															
200-300						1	2	1	2	3			1		
100-200							4		4			1	2		
Recede															
300+															
200-300									1	1		1			
100-200							1		1	1	1	2	2		1
Total						1	7	1	8	5	1	4	5		1
TOTAL						1	9	5	12	11	11	9	10	1	6

Fig. 13 - Wall Display S_2 - 1305 Hours - Schedule Day

[redacted]